Bulletin No. 39.—W. B. No. 463. Issued December 2, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

A COURSE IN METEOROLOGY AND PHYSICAL GEOGRAPHY.

BY

W. N. ALLEN.

INSTRUCTOR IN PHYSICAL GEOGRAPHY,
TACOMA HIGH SCHOOL, TACOMA, WASH.

Published under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

Copies of this publication may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 20 cents each.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU, OFFICE OF THE CHIEF,
Washington, D. C., August 1, 1911.

Hon. JAMES WILSON,
Secretary of Agriculture.

SIR: I have the honor to transmit herewith a paper entitled "A Course in Meteorology and Physical Geography," which has been prepared by Prof. W. N. Allen, of the Tacoma High School, Tacoma, Wash.

Most of this course treats of meteorology, to which the other portions are cognate and introductory. If published, it would be of value to the Weather Bureau, both indirectly by increasing the attention given to meteorology in our high schools and also directly by guiding the younger men of the service in their elementary studies. I therefore recommend its publication as Weather Bureau Bulletin No. 39.

Very respectfully,

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

Approved.

JAMES WILSON,
Secretary.

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II. Laboratory Equipment.

A. REFERENCE BOOKS.

1. Davis's Elementary Meteorology.
2. Waldo's Elementary Meteorology.
3. Realm of Nature.
4. Story of Atmosphere.
5. Moore's Descriptive Meteorology.
6. About the Weather.
7. Tarr's Physical Geography.
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II. Laboratory Equipment.

A. REFERENCE BOOKS.

1. Davis's Elementary Meteorology.
2. Waldo's Elementary Meteorology.
3. Story of Atmosphere.
4. Realm of Nature.
5. Moore's Descriptive Meteorology.
6. About the Weather.
7. Tarr's Physical Geography.
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A. REFERENCE BOOKS.

1. Davis's Elementary Meteorology.
2. Waldo's Elementary Meteorology.
3. About Weather.
4. Treatise on Winds.
5. Moore's Descriptive Meteorology.
6. Realm of Nature.
7. Tarr's Physical Geography.
8. Dryer's Physical Geography.
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II. Laboratory Equipment.

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2. Waldo's Elementary Meteorology.
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6. Tarr's Physical Geography.
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II. Laboratory Equipment.

A. reference books.

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4. Geography of the Sea.
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B. apparatus, etc.

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EXERCISE I. THE GLOBE.

I. Directions, etc.

1. Draw upon unruled paper colored globe about 4 inches in diameter from actual inspection of globe. (2) Incline globe toward right 23½ degrees. (3) Use protractor to determine angles. (4) Read Realm of Nature, pages 78–80, or Moore, pages 69–74.

2. Place upon drawing in proper positions following lines with names: (*a*) Axis, (*b*) equator, (*c*) tropics, (*d*) ecliptic, (*e*) meridians, (*f*) polar circles. (2) Test accuracy of work by comparing it with standard globes.

3. Place upon globe names and widths in degrees of following zones: (*a*) North Frigid, (*b*) South Frigid, (*c*) North Temperate, (*d*) South Temperate, (*e*) Torrid.

4. Determine following points from actual inspection of mariner's compass: (*a*) North, (*b*) south, (*c*) east, (*d*) west, (*e*) northeast, (*f*) southeast, (*g*) northwest, (*h*) southwest. (2) Name objects that are situated (*a*) north, (*b*) south, etc., of high school. (3) State direction of high school from home.

5. Record daily for month wind directions and conditions of sky, whether (*a*) clear, (*b*) cloudy, or (*c*) partly cloudy. (2) Use cross-ruled paper, mariner's compass, and wind vane upon roof. (3) Read Chapter IX, Salisbury, page 60, Realm of Nature, or Appendix F, Tarr. (4) Prepare summary. (5) Determine from charts where magnetic poles, north and south, are located. (6) Locate line of no variation in America.

II. Written Review.

1. Define names in Nos. 2 and 3. (2) How is degree upon circle determined? (3) Upon what does length of degrees depend? (4) How do degrees of longitude differ in length from degrees of latitude? (5) Insert table, page 25, Dryer, and explain.

2. Compare inclination of earth's axis with (*a*) position of tropics, (*b*) polar circles, and (*c*) widths of Frigid and Torrid Zones. (2) Where would polar circles and tropics be located if earth's axis were inclined 45 degrees, 20 degrees, 10 degrees, or 0 degrees? (3) State widths of zones in each case.

3. State where vertical sun would shine continuously if earth were not inclined upon its axis. (2) Use globe suspended from axis and light to illustrate. (3) Define (*a*) latitude and (*b*) longitude. (4) State (*a*) from what lines latitude and longitude are reckoned and (*b*) greatest number of degrees in each. (5) Give approximate longitude, and latitude of this city.

4. Which way does earth rotate? (2) Give proofs. (3) How long does it take to rotate once? (4) Show by use of rotator and centrifugal hoops effects of rotation upon shape of earth. (5) Illustrate by means of light and globe effects of rotation upon distribution of sunlight and heat. (6) Show by use of globe relation between longitude and time.

5. Find approximate difference in longitude and difference in time between Tacoma and New York. (2) Use tellurian, or map, and read Salisbury, page 311. (3) Locate parallel 40 or 45 degrees north. (4) State near or through what cities line passes. (5) Locate upon map and make sectional diagram, 6 by 6 inches, of township 18 north and range 4 east; number sections. (6) Subdivide section 16 into quarters. (7) Locate in red upon diagram and describe in words northeast quarter of section 16. (8) How is land usually described in deeds and tax receipts? (9) Use map of State or United States.

6. State difference between "Magnetic north" and "Polar north." (2) About how many degrees and in what direction is "declination" of magnetic needle in this city? (3) State where line of no variation is located in America.

III. Reference Books.

1. Tarr's Physical Geography, Appendix A and B.
2. Young's Astronomy, Chapters III, IV.
3. Moulton's Astronomy, Chapter VI.
4. Salisbury's Physiography, Chapters IX, X.
5. Realm of Nature, Chapter IV.
6. Dryer's Physical Geography, Chapter I.
7. Story of Solar System, Chapter V.
8. Maps of State or World.

EXERCISE II. CHANGE OF SEASONS.

I. Directions, etc.

1. Draw upon unruled paper rectangular figure 3 by 6 inches lengthwise of page. (2) Divide figure into eight squares 1½ inches each.

2. Construct upon rectangle an ellipse, by using diagonal of one square for radii of side arcs, and diagonal of two squares for upper and lower arcs. (2) Extend middle lines of rectangle to intersect ellipse.

3. Draw upon points of intersection globes 1½ inches in diameter, to represent earth (*a*) at autumnal and vernal equinoxes, and (*b*) at winter and summer solstices. (2) Make globes similar to globe in exercise No. 1.

4. Locate sun near center of diagram. (2) See that globe leans 23½ degrees toward right. (3) Make slanting and vertical rays of sun in red. (4) See that sun's rays touch earth in right latitudes. (5) Test accuracy of work by using tellurian or astronomical board.

5. Place upon globe circles and belts as in exercise No. 1. (2) Represent night by shading globe. (3) Letter principal points of diagram A, B, C, D. (4) Date each point to correspond with season represented. (5) Indicate directions of earth's movements by means of arrows. (6) See Moore, page 70, or Waldo, page 73.

II. Written Review.

1. State difference between ellipse and circle. (2) What is meant by "Major" and "Minor" diameters of ellipse? (3) State upon which diameter earth is on June 21 and December 21. (4) What are terminal points of diameter called? (5) State which point is nearest sun. (6) Read Salisbury, page 310.

2. State which way earth leans in respect to sun in June and December. (2) State when earth is farthest from sun. (3) Explain why it is warmer at Cancer in June than in December. (4) Use tellurian to illustrate. (5) Measure astronomical board. (6) Read Salisbury, Chapter X.

3. How many degrees of earth is covered by sunshine at one time? (2) How far and in what direction do extreme slanting rays extend from vertical rays? (3) Test answers by comparing them with tellurian.

4. State definitely three conditions that cause change of seasons. (2) Test accuracy of statements by use of tellurian. (3) Explain why length of day and night varies.

5. State latitude of vertical and extreme slanting rays at A. (2) Name seasons at each tropic, and the equator at A, also (3) comparative length of day and night, and (4) condition of light at each pole at A. (5) Do likewise with B, C, and D in separate paragraphs.

III. Reference Books.

1. Tarr's Physical Geography, Appendix A and B.
2. Waldo's Elementary Meteorology, Chapter II.
3. Realm of Nature, Chapter V.
4. Moore's Descriptive Meteorology, Chapter VII.
5. Young's Astronomy, Chapter IV.
6. Dryer's Physical Geography, Chapter I.
7. Salisbury's Physiography, Chapter X.
8. Diagrams upon Wall.

EXERCISE III. SOLAR SYSTEM.

I. Directions, etc.

1. Draw full-page diagram showing (*a*) relative positions, (*b*) relative sizes of planets in solar system. (2) Indicate direction of movements of planets by means of arrows. (3) Use tellurian. (4) See Tarr, figure 8, for radii, also Yagg's Chart of Solar System.

2. Draw diagram showing relative size of planets. (2) Insert diameters in red. (3) See Story of Solar System, page 11, or Tarr, pages 4 and 5.

3. Make table, full width of page, showing following summary of facts relating to bodies in solar system.

General summary of solar system.

No.	Planet.	Density.	Dist.	Rot.	Rev.	Incl.	No. Sat.	Diam.	Etc.

4. Abbreviate items in summary wherever possible. (2) See Young, page 402, or Story of Solar System, page 182, for form of diagram and summary of facts.

5. Draw diagram showing inclination of each planet. (2) Draw in black with inclination axis in red. (3) Represent each planet by means of circle, 2 inches in diameter. (4) See Story of Solar System, page 9. (5) Use protractors.

6. Insert "Bode's Law" with full explanation beneath. (2) See Young, page 190, or Realm of Nature, page 84. (3) Note space between Mars and Jupiter by red circle in diagram No. 1.

II. Written Review.

1. Name proofs that planets are spherical in form. (2) State probable cause. (3) Refer to experiments with rotator and accessories in Exercise I.

2. Name planets according to size. (2) See summary and diagrams. (3) Which planet is densest? (4) Which is least dense?

3. State observation between density of planet and its distance from sun. (2) See summary.

4. Name planets according to distance from sun. (2) See diagrams.

5. Explain "Bode's Law." (2) State wherein it seems to be deficient. (3) Refer to diagram of solar system.

6. State what is thought to be origin of asteroids.

7. What is your observation concerning direction of rotation and revolution of planets?

8. State whether planets rotate and revolve in same direction.

9. State difference between comets and meteors. (2) Planets and suns.

10. State observation concerning direction and inclination of planets. (2) State what inclination of axis has to do with (*a*) change of season, (*b*) length of day and night, and (*c*) width of zones.

III. Reference Books.

1. Tarr's Physical Geography, Chapter I.
2. Tarr's Physical Geography, Appendix A.
3. Dryer's Physical Geography, Chapter I.
4. Moore's Descriptive Meteorology, Chapter IV.
5. Young's Astronomy, Chapter I.
6. Realm of Nature, Chapters V and VI.
7. Story of Solar System.
8. Salisbury's Physiography, Chapter X.

EXERCISE IV. NEBULAR HYPOTHESIS.

I. Directions, etc.

1. State briefly, in series of paragraphs, main features of nebular hypothesis. (2) See Young, page 336, and Realm of Nature, page 92.

2. Make series of drawings, about 4 inches in diameter, to illustrate nebular hypothesis. (2) Make each drawing with brief explanatory statements upon sheet of unruled paper. (3) See nebulæ in references.

3. Write explanatory notes of each drawing upon ruled paper, immediately before or after drawings. (2) See drawings upon wall and illustrations of nebulæ in Young's Astronomy, page 336.

4. State clearly in separate paragraphs purpose of following experiments: (*a*) Rotating hoops, (*b*) rotating governor, (*c*) rotating and revolving balls, and (*d*) rotating liquids in glass globe. (2) Make drawings of experiments to accompany each paragraph.

II. Written Review.

1. Give some reasons why nebular hypothesis is generally accepted. (2) See Young's Astronomy, page 347.

2. Explain following facts regarding planets by means of nebular hypothesis: (*a*) Shape, (*b*) density, (*c*) movements, (*d*) composition, and (*e*) condition in respect to heat. (2) Mention experiments in connection with explanation.

3. Read what is said in reference books concerning "Nebulæ." (2) Give brief summary of readings. (3) State what bearing observed nebulæ have upon nebular theory.

4. State what seems to be chief cause in changing (*a*) gases into liquids or solids, (*b*) in producing spherical form of planets, (*c*) in separating bodies into parts. (2) Give illustration by referring to experiments.

5. State what is probable condition of moon. (2) What is likely to become of oceans and atmosphere of earth in time? (3) What will probably become of sun's heat? (4) Of life upon earth?

III. Reference Books.

1. Tarr's Physical Geography, Chapter I.
2. Tarr's Physical Geography, Appendix A.
3. Dryer's Physical Geography, Chapter I.
4. Young's Astronomy, Chapters I, II.
5. Moulton's Astronomy.
6. Story of the Solar System.
7. Realm of Nature, Chapters V, VI.
8. Yagg's Charts.

EXERCISE V. THE ATMOSPHERE.

I. Directions, etc.

1. Give short description of origin of atmosphere. (2) State briefly what is likely to become of earth's atmosphere in time. (3) Read Story of Atmosphere, page 9, Davis, pages 2–8, or Moore, Chapter I.

2. Insert table, page 275, Dryer. (2) State beneath table three things table is designed to show. (3) State which substance in air is (*a*) lightest, (*b*)

heaviest, (*c*) most abundant, (*d*) most beneficial to plants, (*e*) most injurious to animals. (4) Mention effects of oxygen upon life. (5) Give brief account of nitrogen, its uses, etc.

3. Name five sources of dust particles. (2) Read references to dust. (3) State how dust is distributed through air. (4) Insert tables, page 24, Story of Atmosphere. (5) State what each table is designed to show. (6) Read Moore, pages 29–33.

4. Make colored drawing on unruled paper full length of page of prism and spectrum. (2) Test colors by comparing them with solar spectrum or colored disks. (3) Read Realm of Nature, page 36, and Story of Atmosphere, page 147. (4) Substitute raindrop for prism in drawing and draw rainbow. (5) Experiment with prism.

5. State effect of dust particles upon (*a*) color, (*b*) heat, and (*c*) light of atmosphere. (2) Explain (*a*) color of sky, and (*b*) twilight and dawn. (3) Read Davis, Chapter IV, or Tarr, page 119.

6. Discuss two classes of microbes. (2) State conditions under which microbes thrive. (3) Name some benefits and dangers of microbes. (4) Name some simple means of preventing microbes. (5) Read "Bacteria, etc.," by Conn, Waldo, page 9, or Moore, page 27.

7. Insert upon unruled paper figure 18, page 74, Waldo, or figure 253, page 277, Dryer, lengthwise of page. (2) Substitute Mount Tacoma for mountains in figure. (3) Make drawing three times size of figure in book. (4) State beneath figure, four things figure is designed to show.

II. Written Review.

1. How would slight variation in quantity of oxygen or nitrogen affect life of animals? (2) Read Story of Atmosphere, or Moore, Chapter II.

2. Where is carbon dioxide most plentiful? (2) Was it ever more plentiful? (3) Give reasons for each statement. (4) Read Realm of Nature, page 263, and Story of Atmosphere, page 20. (5) Give brief account of some noted "Death gulch." (6) State briefly what makes such gulches dangerous. (7) Read Davis, pages 5–6.

3. Name five uses of dust particles. (2) Where is dust most plentiful? (3) State briefly chief uses and work of atmosphere. (4) Explain why water vapor floats in air. (5) See Table No. 1.

4. Define color. (2) Name seven prismatic colors. (3) Explain formation of (*a*) colored sunsets, and (*b*) rainbows. (4) Explain formation of spectrum and rainbow.

5. Account for presence of water vapor in air. (2) Mention its uses. (3) Does water vapor weight more or less than dry air? (4) Give some proofs.

6. State how nebular hypothesis explains origin of atmosphere. (2) Read Realm of Nature, pages 92–94, or Moore, Chapter IV.

III. Reference Books.

1. Story of Atmosphere, Chapters I, II.
2. Waldo's Elementary Meteorology, Chapter I.
3. Davis's Elementary Meteorology, Chapters I–IV.
4. Moore's Descriptive Meteorology, Chapters I, II, III.
5. Realm of Nature, Chapter VII.
6. Tarr's Physical Geography, Chapter XII.
7. Dryer's Physical Geography, Chapter XXII.
8. Salisbury's Physiography, Chapters XI, XII.

EXERCISE VI. HEAT.

I. Directions, etc.

1. Read references to heat. (2) Keep for time end of wire in flame. (3) Test temperature of other parts. (4) Make drawings to illustrate experiments upon upper part of unruled sheet and explanatory notes on lower half. (5) Define (*a*) radiation, (*b*) absorption, and (*c*) conduction of heat. (6) Name some natural objects that are good (*a*) radiators, (*b*) absorbers, and (*c*) conductors of heat.

2. Burn small quantity of gasoline upon water in test tube and hold wire above flame. (2) Test temperature of water beneath flame and wire above. (3) Explain difference in temperature of water and wire. (4) Make, letter, and explain drawing. (5) Define (*a*) reflection and (*b*) absorption of heat.

3. Pass metal ball through ring. (2) Heat ball and try to repeat. (3) Cool ball or heat ring and repeat. (4) Observe effect of heat and of cold upon size of solids. (5) Make, letter, and explain drawings as in No. 1.

4. Place test tube with water over flame. (2) Note change in volume of water. (3) Make two drawings upon upper part of paper to illustrate effect of heat upon volume of liquids. (4) What causes water to boil over?

5. Hold corked test tube over flame. (2) Observe results. (3) Make, letter, and explain two drawings. (4) What effect has heat upon volume of gases? (5) What causes gas tanks or boilers to explode?

6. Imagine small quantity of ice or sulphur in dish over flame. (2) Note changes in form. (3) What is it that changes (*a*) solids to liquids and (*b*) liquids to gases? (4) Name three forms of matter. (5) Make and explain two drawings.

7. Place side of bent tube, convection apparatus, containing liquid over flame. (2) Indicate direction of circulation by means of colored arrows in drawing half page size. (3) Define convection. (4) What causes water to circulate? (5) What causes ocean currents?

8. Place flame in left tube of convection apparatus. (2) Hold lighted torch above each tube. (3) Make drawing on upper part of page. (4) Indicate direction of air currents by colored arrows. (5) What causes air to circulate? (6) Read Moore, page 51.

II. Written Review.

1. Define matter. (2) Discuss structure of matter. (3) Read Realm of Nature, page 27. (4) Give examples of each form of matter. (5) State effect of intense cold upon (*a*) water and (*b*) air. (6) Read Moore, page 26.

2. Define heat. (2) Discuss four original sources of heat. (3) State which source is most important to earth. (4) State effect of intense heat upon (*a*) solids and (*b*) liquids.

3. Explain why volume of warm air or water should weigh less than same volume of cold air or water. (2) State why smoke rises in flue.

4. Explain why cold water flows toward the fire box and warm water rises in water tank. (2) Give location of hottest and coldest belts upon earth. (3) Which way does air and water of globe flow in respect to heat and cold belts? (4) See maps of winds and ocean currents in reference books.

5. Which is better reflector, land or water surface? (2) Explain why continents are warmer in summer than oceans.

6. Explain in separate paragraphs and give examples in nature of (*a*) radiation, (*b*) absorption, (*c*) reflection, (*d*) conduction, (*e*) convection. (2) State what causes liquids and gases to circulate. (3) State by what means large buildings and ocean steamers are usually ventilated.

III. Reference Books.

1. Realm of Nature, Chapters I, II, III.
2. Story of Atmosphere, Chapter IV.
3. Moore's Descriptive Meteorology, Chapters V, VII.
4. Books on Physics.
5. Davis's Elementary Meteorology, Chapter III.
6. Waldo's Elementary Meteorology, Chapter II.
7. Salisbury's Physiography, Chapter XIII.

EXERCISE VII. THERMOMETERS.

I. Directions, etc.

1. Read what is said in references concerning thermometers and thermographs. (2) Record upon cross-ruled paper daily for month, temperature of room by means of (*a*) Fahrenheit and (*b*) Centigrade thermometers.

2. Keep over flame thermometer tube containing small quantity of air and mercury, until mercury fills tube. (2) Seal tube and allow mercury to cool. (3) What is space above mercury called? (4) Make upon upper part of page three drawings of experiments about 4 inches long. (5) Explain drawings separately upon lower part of page.

3. Keep lower part of tube submerged in cracked ice or snow until contraction of mercury ceases. (2) Mark point of minimum contraction of mercury. (3) What is point called? (4) Make drawing of experiment and explain beneath.

4. Suspend thermometer tube in long-neck flask containing boiling water. (2) Cork neck of flask. (3) Mark maximum expansion of mercury in tube. (4) What is point called? (5) Make drawing of experiment and explain beneath.

5. Draw two thermometers, Fahrenheit and Centigrade, 25 centimeters long, upon metric ruled or blank paper. (2) Make drawings in form of rectangle. (3) Make upper and lower lines of diagrams indicate boiling and freezing points of water, and 18 centimeters apart. (4) Grade each instrument by dividing space between boiling and freezing points into required number of parts. (5) See that readings of thermometers correspond. (6) Notice that thermometers register actual temperature of room.

6. Draw from inspection maximum and minimum thermometers. (2) Explain drawings. (3) See that readings in drawings are same as readings upon thermometers. (4) How does steel index work? (5) Mention use of constriction. (6) Read Davis, page 60.

II. Written Review.

1. Describe in separate paragraphs kinds of material necessary for construction of thermometers. (2) Give reasons for use of each material. (3) State how each thermometer tube is graded.

2. Describe (*a*) how vacuum is formed in thermometer tube and mention its use; (*b*) how freezing point is determined; (*c*) how boiling point is determined; (*d*) how one degree upon each thermometer tube is determined.

3. Deduce formulas for transposing terms of one thermometer into terms of another. (2) Test formulas by transposing daily readings of one thermometer into readings of another thermometer. (3) Use daily record No. 1.

4. Name some advantages or uses of maximum and minimum thermometers. (2) Give short description of construction and use of each instrument. (3) What kind of liquid is used in minimum thermometer? Why?

5. What principle is used in construction of thermometers? (2) For what does zero stand upon each instrument? (3) What is meant by absolute zero? (4) What is cold? (5) See paper thermometer on wall for low readings and absolute zero; also Moore, pages 54–55.

III. Reference Books.

1. Tarr's Physical Geography, Appendix G.
2. Waldo's Elementary Meteorology, pages 31–33.
3. Davis's Elementary Meteorology, Chapter V.
4. Moore's Descriptive Meteorology, Chapter VI.
5. Realm of Nature, pages 341–342.
6. Story of Atmosphere, page 39.
7. Dryer's Physical Geography, Appendix.
8. Salisbury's Physiography, Chapter XIII.

EXERCISE VIII. DAILY CHANGE IN TEMPERATURE.

I. Directions, etc.

1. Draw thermograph, full-page size, from inspection of instrument. (2) Letter principal parts of drawing. (3) Mention use of each part. (4) Make cylinder, full size. (5) Indicate direction of movement of cylinder by means of arrows. (6) State what part of thermograph expands and contracts. (7) What turns cylinder? (8) See thermograph and read Davis, page 58.

2. Notice how sheet upon cylinder is lined and numbered. (2) State what lines and spaces between lines represent. (3) What does line made by pen upon sheet represent? (4) What is sheet and pen line called?

3. Draw from thermal sheets upon sheet of metric paper two thermal lines in red. (2) Make first line to represent changes in temperature for two consecutive clear days. (3) Make second line to represent two consecutive cloudy days. (4) See thermal sheets for clear and cloudy weather. (5) Begin lines at midnight. (6) Allow one centimeter for two hours. (7) One centimeter for 5°. (8) Date lines as per thermal sheets. (9) Fold sheet lengthwise. (10) Use upper and lower halves separately.

4. State when (*a*) minimum and (*b*) maximum temperature of each day occurs. (2) Find difference in daily extremes of temperature. (3) What is difference called? (4) Compare range of temperature during clear and cloudy weather. (5) Read Dryer, page 28, or Tarr, page 241.

5. Insert table, page 28, Waldo. (2) Illustrate table by drawing upper part of figure 392 in Tarr full width of page. (3) Make lines represent sun's rays at angles given in table, and 1 centimeter in width. (4) Place table and drawing on same page. (5) State three facts table is designed to show. (6) See diagrams upon wall.

6. Select from summer "weather map," and give date, (*a*) 10 interior cities and (*b*) 10 seaport cities. (2) Find their average (*a*) maximum, (*b*) minimum, and (*c*) range of temperature. (3) Make averages in red. (4) Compare averages in temperature of interior cities with those of seaport cities. (5) Give reasons for difference observed. (6) See form for tabulation on wall.

II. Written Review.

1. State what part of thermograph is substituted for mercury in thermometer. (2) State how change of temperature is communicated to pen. (3) Name some advantages of thermographs. (4) State how thermal sheet is ruled and numbered. (5) How does thermal line show changes in temperature?

2. Express in words ordinary change in temperature for one clear day. (2) Explain fully (*a*) why maximum temperature occurs about middle of afternoon, and (*b*) minimum about sunrise. (3) State what you observe concerning (*a*) maximum, (*b*) minimum, and (*c*) range of temperature during clear and cloudy weather. (4) Give reasons for observations.

3. What kind of temperature should be expected (*a*) upon clear nights in winter, (*b*) upon clear days in summer? (2) How would low temperature affect water pipes and plants? (3) State what you observe, and give reasons in each case.

4. Compare averages of interior cities with averages of seaport cities. (2) State effect of water bodies and dry places upon (*a*) maximum, (*b*) minimum, and (*c*) range of temperature. (3) Account for differences of temperature between eastern and western Washington. (4) Read Dryer, page 300.

5. State relation between (*a*) angle of sun and amount of heat received, (*b*) angle of sun and amount of surface covered, (*c*) units of atmosphere and amount of heat. (2) See table and illustration in No. 5.

III. Reference Books.

1. Waldo's Elementary Meteorology, Chapter II.
2. Tarr's Physical Geography, Chapter XII.
3. Dryer's Physical Geography, Chapter XXV.
4. Moore's Descriptive Meteorology, Chapters VI, VII.
5. Story of Atmosphere, Chapter IV.
6. Story of Atmosphere, figures 4, 5.
7. Davis's Elementary Meteorology, Chapter V.
8. Salisbury's Physiography, Chapter XIII.

EXERCISE IX. SEASONAL CHANGE IN TEMPERATURE.

I. Directions, etc.

1. Draw in red, upon chart of world, isotherms for July. (2) Number lines as per chart. (3) Note how thermal numbers increase or decrease in respect to equator. (4) Locate definitely and color places of greatest heat. (5) See thermal charts for July and January in reference books, also charts 2 and 3, Moore.

2. Note whether or not isotherms bend toward or away from equator in crossing continents. (2) Do same in respect to oceans. (3) State what bends observed indicate regarding comparative temperature over land and sea in July.

3. Compare positions of isotherms of 70° north and south in respect to equator. (2) Note comparative latitude of same thermal line near eastern and western coasts of continents. (3) Determine whether or not temperature is equal in same latitudes north and south, and east and west.

4. Treat January chart in same manner as July chart, and repeat Nos. 1, 2, 3.

5. Read Tarr, pages 276 to 279, prepare summary with examples to illustrate what is said concerning influence of (*a*) latitude, (*b*) altitude, (*c*) oceans, (*d*) deserts, and (*e*) north and south slopes upon temperature. (2) Read Moore, page 115, or Waldo, page 53.

6. Determine, by use of tellurian, latitude of vertical sun on June 21 and December 21. (2) Illustrate same by drawing together in red and black, figures 549 and 551, Tarr. (3) Compare positions of maximum temperature for July and January. (4) Prepare reasons for changes in positions.

II. Written Review.

1. State how temperature increases or decreases in respect to latitude. (2) Give reasons. (3) See No. 5, Exercise VIII. (4) Name countries which are hottest in July. (5) Give at least two reasons. (6) Do same in respect to January.

2. State which way thermal lines bend in crossing oceans, in (*a*) summer, and (*b*) winter. (2) Do same in respect to continents. (3) Give reasons in each case. (4) Give reasons why thermal lines do not coincide with parallel lines.

3. Compare isotherms south with same isotherms north of equator in respect to regularity. (2) Do same in respect to land and water surfaces. (3) Give reasons for observations.

4. State in separate paragraphs and give examples of influence of (*a*) altitude, (*b*) latitude, (*c*) oceans, (*d*) winds, (*e*) ocean currents, (*f*) clouds, (*g*) desert, and (*h*) direction of mountain slopes upon temperature. (2) Give reasons why all places in same latitude do not have same temperature. (3) Define (*a*) isothermal line, (*b*) thermal equator. (4) Locate thermal equator and state why so located.

5. State upon what lines sun is vertical June 21 and December 21. (2) Explain why (*a*) maximum temperature occurs in July and (*b*) minimum in January. (3) State what causes thermal lines and belts to change positions.

6. Name principal places in North America through which July isotherms of 60° passes. (2) Do same with January line of 60°. (3) Give reasons for difference in position and regularity of line.

III. Reference Books.

1. Waldo's Elementary Meteorology, Chapter II.
2. Tarr's Physical Geography, Chapter IV.
3. Story of Atmosphere, Chapter IV.
4. Moore's Descriptive Meteorology, Chapter VII.
5. Realm of Nature, Chapter VII.
6. Davis's Elementary Meteorology, Chapter V.
7. Dryer's Physical Geography, Chapter XV.
8. Salisbury's Physiography, Chapter XIII.

EXERCISE X. BAROMETERS.

I. Directions, etc.

1. Record daily for month, upon cross-ruled paper, atmospheric pressure as indicated upon barometer or barograph. (2) Date sheet. (3) Record kind of weather as "Fair," "Cloudy," "Rainy," etc. (4) Continue to record temperatures. (5) Read Ward's Exercises in Elementary Meteorology, Chapter I.

2. Read references concerning barometers and barographs. (2) State what demonstrations with (*a*) air pump, (*b*) inverted glass of water, and (*c*) balances are designed to show. (3) Read Davis, page 82, Moore, pages 127–132, or Waldo, page 75.

3. Fill glass tube about 3 feet long with mercury. (2) Invert filled tube in bowl containing mercury. (3) Observe that end of tube does not rest on bottom of bowl. (4) Notice that mercury has fallen in tube. (5) What is empty space above mercury called? (6) How is it formed? (7) What keeps mercury up in tube?

4. Draw upon metric or unruled paper-bent tube; tube and bowl and stand together. (2) Make tubes about 24 centimeters long and 1 centimeter wide. (3) Make bowl and bend in tube about 4 centimeters across. (4) See apparatus, drawings upon wall, and illustrations in reference books.

5. Grade tubes from 25 to 35 inches by allowing two and one-half centimeters for each inch. (2) See that mercury in bowl and tube is on same level. (3) Measure height of mercury in tubes from surface of mercury in bowl and tube. (4) Compare measurements with actual readings upon standard barometers.

6. Insert table, page 75, Waldo. (2) State what table is designed to show. (3) Determine which weighs more per cubic foot, (*a*) dry air or water vapor, (*b*) warm or cold air. (4) How does barometer stand during rainy weather? Why? (5) Read Story of Atmosphere, page 27.

II. Written Review.

1. How high is atmosphere supposed to extend? (2) Read Moore, page 8, or Davis, page 13. (3) What is weight or pressure of atmosphere on square inch; on square foot? (4) In which direction is pressure exerted? (5) Refer to experiments.

2. What effect has altitude upon pressure? Why? (2) Give approximate pressure of atmosphere upon summit of Mount Tacoma (14,500 feet) when barometer registers 30 inches at sea level. (3) State effect of water vapor in air upon barometric pressure. (4) Read Moore, page 200, or Davis, page 143.

3. Compare weight of mercury with that of water. (2) How high will water rise in vacuum? Why? (3) How high will mercury rise in vacuum? Why? (4) What causes water to rise in ordinary pumps or tubes? (5) Explain what is meant by suction.

4. State briefly history of barometer. (2) Read Story of Atmosphere, page 25. (3) Describe how vacuum is formed in barometer tube. (4) Mention use of vacuum. (5) Describe how simple barometer is constructed and graded.

5. Compare working of balances with working of barometer. (2) State principle used in construction of barometers. (3) Give reasons for use of long tube. (4) Why is mercury used in barometers?

6. Name practical uses of barometers. (2) Express in inches what constitute (*a*) high, (*b*) low, and (*c*) normal barometers at sea level. (3) State kind of weather indicated by "Low" and by "High" barometers. (4) Give reasons in each case.

III. Reference Books.

1. Waldo's Elementary Meteorology, Chapter III.
2. Davis's Elementary Meteorology, Chapter VI.
3. Story of Atmosphere, Chapter III.
4. Moore's Descriptive Meteorology, Chapter IX.
5. Tarr's Physical Geography, pages 420–422.
6. Dryer's Physical Geography, Chapter XXVI.
7. Marvin's "Barometers, etc."
8. Salisbury's Physiography, Chapter XV.

EXERCISE XI. DAILY CHANGE IN PRESSURE.

I. Directions, etc.

1. Continue to record daily barometric pressure. (2) Record daily whether or not barographic line is "rising," "falling," or "even." (3) Note kind of line associated with unusually "good" or "bad" weather, also with severe "storms" or "violent" winds. (4) Observe barographs daily.

2. Read Davis, page 84, and Moore, page 131. (2) Draw barograph full page size from inspection of instrument. (3) Letter principal parts of drawings. (4) State use of each part. (5) Make cylinder full size. (6) What turns cylinder?

3. Note how sheet upon cylinder is ruled, lettered, and numbered. (2) State what lines and spaces between lines represent. (3) What does line made by pen upon sheet represent? (4) What is sheet and pen line called?

4. Draw from barographic sheets upon metric ruled paper two barographic lines in red. (2) Make first to represent "clear" or "good" weather. (3) Make second to represent "rainy" or "bad" weather. (4) See barographic sheets for "good" and "bad" weather. (5) Begin lines at midnight. (6) Allow 2.5 centimeters per inch. (7) Allow 1 centimeter for six hours. (8) Date lines as per sheets. (9) Fold metric sheets lengthwise. (10) Use upper and lower halves separately.

5. Determine from inspection of lines, interval of time usually between one maximum and another. (2) Compare two barographic lines. (3) State which one has higher pressure. (4) Apply and remove pressure by breathing through attached tube on demonstration barometer. (5) What does demonstration show?

II. Written Review.

1. State what part of barograph is substituted for mercury in standard barometer. (2) Name two parts of barograph that correspond to two parts of balances. (3) Which way does cylinder turn in respect to pen?

2. Explain how changes in pressure are communicated to pen. (2) State how barographic line indicates change in pressure. (3) What kind of line indicates (*a*) "good," (*b*) "bad," (*c*) stormy weather, or (*d*) violent winds?

3. State from inspection of barometric line approximate interval of time usually between maximum and minimum pressures. (2) State how often weather conditions usually change. (3) State what kind of weather is indicated (*a*) by "rising" barographic line, (*b*) by "falling" line, (*c*) by "even" or straight line, (*d*) by "very steep" or V-shaped line. (4) Read Dryer, page 324.

4. Mention advantages of barographs. (2) Name some practical uses of barographs and barometers to (*a*) sailors, (*b*) farmers, (*c*) mountaineers, (*d*) builders, and (*e*) aviators. (3) Explain how altitude is determined by barometers.

5. State effect of atmospheric pressure upon breathing. (2) How does water vapor in air affect barographs? (3) State how barographs indicate increase or decrease in air pressure and change of weather. (4) Give brief description of aneroid barometers. (5) See instrument and read Moore, page 130.

III. Reference Books.

1. Waldo's Elementary Meteorology, Chapter III.
2. Davis's Elementary Meteorology, Chapter VI.
3. Story of Atmosphere, Chapter III.
4. Moore's Descriptive Meteorology, pages 127–138.
5. Tarr's Physical Geography, pages 420–422.
6. Dryer's Physical Geography, Chapter XXVI.
7. Marvin's "Barometers, etc."
8. Salisbury's Physiography, Chapter XVI.

EXERCISE XII. SEASONAL CHANGE IN PRESSURE.

I. Directions, etc.

1. Draw colored isobaric chart of world for July. (2) Number isobaric lines as per chart. (3) Print upon chart word "High" or "Low" in proper areas, north and south. (4) See isobaric charts in reference books.

2. Locate places of maximum and minimum pressures in middle latitudes, north and south. (2) Notice whether high pressures are mostly over land or

sea. (3) Notice in about what latitude high-pressure areas are located. (4) See charts, and Waldo, page 96, or Moore, page 134.

3. Draw isobaric chart of world for January, and repeat as in Nos. 1 and 2.

4. Compare latitude of July high pressure north with January high pressure. (2) Compare their positions in respect to land and water surfaces. (3) Prepare reasons for change observed. (4) What effect has heat upon pressure? (5) Compare extent of high pressure in winter with that in summer.

5. Indicate upon charts wind directions by means of arrows. (2) Observe whether or not surface air moves toward or from high-pressure belts. (3) Note which way winds blow in respect to continents (*a*) in summer, and (*b*) in winter. (4) See Realm of Nature, pages 116 and 124, or Waldo, pages 91 and 93.

6. Determine which weighs more per unit volume, warm air or cold air. (2) Note positions of "High" and "Low" pressures in summer and in winter in respect to land and water. (3) Read Story of Atmosphere, page 27, and prepare summary.

II. Written Review.

1. State in what ways atmosphere pressure is represented upon charts. (2) What are pressure lines called? (3) In what terms are such lines numbered? (4) What line separates "High" and "Low" pressure areas? (5) What are areas without line called? (6) Read Moore, page 135.

2. Compare extent of surface covered by high pressure in summer with that in winter. (2) Compare temperature over land with pressure over land (*a*) during winter and (*b*) during summer. (3) Do same in respect to oceans. (4) State relation of heat and pressure. (5) State why pressure is low in equatorial belt.

3. What effect has heat upon pressure? (2) Explain why pressure belts and line change positions with change of seasons. (3) See barometric charts for July and January. (4) Give example to illustrate answer.

4. Compare summer pressure with winter pressure over continents. (2) How is wind direction indicated upon maps? (3) State which way winds blow in respect to land and water masses in (*a*) summer and (*b*) winter. (4) State which way winds blow in respect to high and low pressure areas. (5) Which way streams flow in respect to high and low places.

5. How does warm air compare in weight to cold air? (2) Explain why air rises over hot places and settles over cold places. (3) Why does wind blow toward land in summer and away from it in winter? (4) Why should pressure be greater upon land in winter than in summer?

III. Reference Books.

1. Davis's Elementary Meteorology, Chapters II–VI.
2. Waldo's Elementary Meteorology, Chapter III.
3. Realm of Nature, pages 116–124.
4. Moore's Descriptive Meteorology, pages 127–138.
5. Story of Atmosphere, Chapter III.
6. Dryer's Physical Geography, Chapter XXVI.
7. Salisbury's Physiography, Chapter XV.
8. Bartholomew's Physical Atlas.

EXERCISE XIII. PRESSURE AND WINDS.

I. Directions, etc.

1. Determine average latitude, north and south, of high and low pressure belts for year. (2) See page 96, Waldo, or Moore, page 134. (3) Draw upon chart of world in latitudes given, colored belts, half centimeter wide, to represent

pressures. (4) Place in belts (*a*) words "High" or "Low" in proper places; also (*b*) pressures in figures.

2. Indicate by arrows directions of winds in each belt. (2) Note relation between wind directions and pressure belts. (3) Read Tarr, page 255. (4) Rotate black globe from west to east. (5) Note effect of rotation upon wind direction in (*a*) equatorial, and (*b*) temperate belts. (6) Read Dryer, pages 306–311, or Moore, page 141.

3. Print upon chart in proper belts, (*a*) northeast trades, (*b*) southeast trades, (*c*) westerlies, and (*d*) circumpolar. (2) Note wind direction and latitude of each wind belt. (3) Do wind belts change positions? Why? (4) See Davis, page 121, or Moore, page 140.

4. Draw lengthwise, upon lower half of metric ruled paper, cross-section of chart No. 1. (2) Allow 1 centimeter for each 10 degrees of latitude. (3) Allow 2 millimeters for each tenth inch of pressure. (4) Insert pressures in figures in proper latitudes. (5) Indicate wind directions and slopes by lines and arrows. (6) Insert names of winds in proper places. (7) See Davis, page 89, or Waldo, page 97.

5. Describe, by means of cross-section, circulation of atmosphere from equator to poles and return. (2) Give (*a*) name, (*b*) direction, (*c*) latitude and altitude of winds in each belt. (3) State what makes air rise near equator. (4) What makes air settle near 30 and 35 degrees, north and south.

6. Determine what is meant by barometric gradient. (2) How is value of gradient determined? (3) Read Waldo, page 100, Salisbury, page 396, or Moore, page 135. (4) Show meaning by use of cross-section. (5) How does gradient effect velocity of winds? (6) What kind of wind does V-shaped or very steep barographic line represent?

II. Written Review.

1. Explain what causes winds. (2) Explain effect of earth's rotation upon wind direction in (*a*) equatorial and (*b*) temperate belts. (3) Mention wind directions in each belt, if earth did not rotate. (4) What causes low pressure near equator? (5) What causes high pressure near middle latitudes? (6) What causes low pressure near latitudes 65°, north and south?

2. Give latitudes, (*a*) directions and (*b*) character, of following winds and wind belts in separate paragraphs: (*a*) Trades, (*b*) antitrades, (*c*) prevailing westerlies, (*d*) horse latitudes, (*e*) circumpolar winds, (*f*) return westerlies, and (*g*) belt of calms. (2) Read Davis, page 117, Tarr, pages 258 to 262, or Moore, page 178.

3. State in separate paragraphs effect of winds upon (*a*) ocean currents, (*b*) ocean commerce, (*c*) surface of earth, (*d*) distribution of moisture, (*e*) distribution of plant life, (*f*) equalization of temperature, (*g*) and general health.

4. Determine by use of cross-section value of gradients for trades and westerlies north. (2) How is velocity of winds indicated upon barometric sheets? (3) Mention some practical uses of winds.

III. Reference Books.

1. Waldo's Elementary Meteorology, Chapters III–VIII.
2. Realm of Nature, Chapter VIII.
3. Ferrel's "Winds."
4. Moore's Descriptive Meteorology, Chapters IX, X.
5. Davis's Elementary Meteorology, Chapter VII.
6. Dryer's Physical Geography, Chapter XXVI.
7. Story of Atmosphere, Chapter V.
8. Salisbury's Physiography, Chapters XV, XVI.

EXERCISE XIV. WIND DIRECTIONS AND RAINFALL.

I. Directions, etc.

1. Trace in ink upon chart of world or each continent (*a*) shore lines, (*b*) rivers, (*c*) lakes, and (*d*) mountains. (2) Indicate in colors and figures upon each continent rainfall for summer. (3) Insert names and indicate wind directions in each belt. (4) Print word "Dry" in red upon places dry for one season and word "Desert" on places dry for years. (5) Insert upon chart words "High" or "Low" in proper places upon oceans, north and south. (6) See charts for wind directions and rainfall.

2. Note general directions of (*a*) mountains and (*b*) river systems upon each continent. (2) Determine between what parallels north and south (*a*) trade winds and (*b*) prevailing westerlies are situated. (3) State whether or not winds blow toward or away from continents upon eastern or western coasts in (*a*) trade and (*b*) westerly belts. (4) Observe whether or not deserts are situated upon "windward" or "leeward" side of mountain ranges. (5) Observe same in respect to rain belts. (6) Note whether or not river systems generally flow with or against prevailing wind directions. (7) Read Dryer, pages 327 to 334; Tarr, pages 22 to 30; or Moore, pages 265 to 266.

3. Draw chart of world or continents for winter and repeat data in Nos. 1 and 2.

4. Draw upon charts of United States or Washington (*a*) wind directions and (*b*) rainfall in colors and inches for July and January. (2) See wind charts for summer, Dryer, pages 305 to 330. (3) Note difference in wind directions and rainfall for July and January. (4) State causes of changes. (5) See Government rain charts for summer and winter.

5. Record wind directions daily for month. (2) Use initial letters, as N., S., NE., SW., etc. (3) Use mariner's compass in determining directions. (4) Observe cloud or smoke drift, also wind vane upon roof. (5) Read (*a*) Salisbury, Chapter IX, (*b*) Realm of Nature, page 60, or (*c*) Tarr, Appendix F.

II. Written Review.

1. State definitely where maximum rainfall in North America occurs in winter and in summer. (2) Explain why maximum rainfall occurs at that season and place. (3) In what wind belt is maximum rainfall in winter and in summer?

2. Repeat No. 1 in separate paragraph in respect to each continent.

3. Give directions of river systems on each continent in respect to (*a*) wind direction and (*b*) mountain systems. (2) Give reasons why Columbia flows west, Amazon east, Mississippi south. (3) Why should Amazon be larger than Columbia? (4) What winds supply La Plata and Orinoco with water? (5) Read Salisbury, pages 396 to 491.

4. State definitely where and in what wind belt each great desert is situated. (2) Give reason why each desert is so located. (3) During what seasons and by what winds is Nile supplied with water? (4) Read Davis, pages 296 to 310.

5. Locate upon each continent rain and rainless belts, if earth were to rotate from east to west. (2) Describe condition (*a*) in South America if Andes were upon eastern side of continent, (*b*) in Australia if mountains were upon western side, and (*c*) in Washington if there were no Cascade Mountains. (3) Describe wind vane upon roof. (4) Which way does arrow point in respect to wind directions? (5) Read Moore, pages 172 to 176.

III. Reference Books.

1. Tarr's Physical Geography, Chapter XIV.
2. Dryer's Physical Geography, Chapter XXVIII.
3. Waldo's Physical Geography, Chapters IV–XII.
4. Salisbury's Physiography, Chapter XVI.
5. Davis's Elementary Meteorology, Chapter XII.
6. Realm of Nature, Chapter IX.
7. Moore's Descriptive Meteorology, page 265.
8. Physical Atlas and Maps.

EXERCISE XV. HIGH AND LOW PRESSURE STORMS.

I. Directions, etc.

1. Read what is said in references concerning cyclones and anticyclones. (2) Continue to record wind directions. (3) Insert in two columns names and velocities of wind in miles. (4) Read Davis, page 94, or Moore, pages 172–177. (5) Determine from inspection of tables what is meant by wind pressure. (6) Determine relation between wind velocity and pressure. (7) Read references relating to anemometers and prepare summary.

2. Insert enlarged half page, figures 29 and 30, Realm of Nature. (2) Print in red words "High" or "Low" in center of figures. (3) Divide figures into quarters by light pencil lines, north and south, east and west. (4) Indicate position of each quarter by inserting in red proper initial, as SE., SW., NW., or NE.

3. Note (*a*) wind directions and (*b*) condition of sky in middle of each quarter of "Low." (2) Note whether or not winds move in or out of low pressure directly or spirally. (3) Observe whether movement is from left or right or otherwise in southern half of "Low." (4) See figures 53 or 58, Davis. (5) Repeat same for "Highs."

4. Insert enlarged upon upper part of paper, figure 292, Dryer, or figure 73, Waldo. (2) Print in centers of whirls words "High" or "Low." (3) Draw pencil line through center of figure and note directions N. and S. (4) Note from figure how winds flow out of high pressure into low pressure in southern halves.

5. Insert upon lower part of page cross and vertical sections of high and low pressure areas, figures 412 and 417, Tarr. (2) Print word "Sky" above each figure and words "High" or "Low" immediately beneath. (3) Note wind directions in center of each pressure. (4) Note relation of barometric line to high and low pressure.

II. Written Review.

1. State differences between "Cyclones" and "Anticyclones," or "Low" and "High" pressure storms; use diagrams. (2) Give directions of spiral whirl in southern half and in center of cyclones. (3) Do same with anticyclones. (4) State effect of (*a*) rising and (*b*) falling air upon barometer.

2. In what direction do low-pressure storms move in (*a*) Equatorial and (*b*) Temperate Zones? (2) Read Dryer, page 318. (3) What part of storm is front? (4) Standing with back to wind, where is center of low pressure, on right or left?

3. State how coming of low-pressure storms are indicated by (*a*) barograph, (*b*) thermograph, (*c*) wind direction, (*d*) condition of sky. (2) Do likewise

with high-pressure storms. (3) What part of low-pressure storms are most dangerous? (4) What instrument is most useful in indicating coming storms?

4. State what wind velocity is considered dangerous to buildings or shipping. (2) State pressure per square foot at velocity mentioned. See tables, Davis or Moore. (3) What is relation between wind velocity and pressure? (4) Explain how wind velocity is measured. (5) How are winds classified? (6) Read Moore, Chapter X.

5. State kind of pressure over north Pacific in (*a*) summer and (*b*) winter. (2) Give direction of winds upon northwest coast of North America in summer and in winter. (3) Mention effect of wind directions on rainfall and give examples.

III. Reference Books.

1. Tarr's Physical Geography, Chapter XIII.
2. Dryer's Physical Geography, Chapter XXVII.
3. Realm of Nature, Chapter IX.
4. Moore's Descriptive Meteorology, Chapters IX–XIII.
5. Story of Atmosphere, Chapters IX–XIII.
6. Waldo's Elementary Meteorology, Chapters VIII, IX.
7. Davis's Elementary Meteorology, Chapter X.
8. Salisbury's Physiography, Chapter XVII.

EXERCISE XVI. WEATHER MAPS.

I. Directions, etc.

1. Draw from selected weather map, upon chart of United States, (*a*) "Low" over Mississippi Valley, (*b*) "High" over eastern and western coasts. (2) Draw isotherms in red and isobars in black. (3) Date chart. (4) Enlarge half inch, characters in explanatory notes upon weather maps. (5) Place enlarged character upon margins of charts.

2. Draw pencil lines through center of "Low" in No. 1 from east to west, north to south. (2) Note from inspection of map (*a*) wind directions, (*b*) temperature, and (*c*) condition of sky respecting clouds, rain, snow, etc., in middle of each quarter, beginning with southeast. (3) For sample chart see No. 19, Moore, or figure 404, Salisbury.

3. Draw as indicated in Nos. 1 and 2 "High" over Mississippi Valley, with "Lows" over eastern and western coasts. (2) Read Realm of Nature, pages 142 to 152. (3) For sample chart see Salisbury, figure 405, or Moore, chart No. 20.

4. Compare (*a*) barometric lines with contour lines, and (*b*) barometric gradient contour slope. (2) State similarity or difference. (3) Note from inspection of map comparative wind velocity in rear and front of storm. (4) Determine which way storms move through United States in temperate belt. (5) Waldo, page 223, or Moore, charts Nos. 32 and 33.

5. Draw in proper colors set of "Storm signals," (*a*) size, 4 centimeters square, black center, one-third width; (*b*) pennants, 8.5 centimeters long and 4 centimeters wide. (2) Draw in proper colors set of "Weather signals." (*a*) size, 4 centimeters square, (*b*) label each signal, and (*c*) state in which quarter of "storm" each signal should appear. (3) See United States signal cards or flags.

II. Written Review.

1. Give wind direction and weather conditions in (*a*) eastern, (*b*) western, and (*c*) central part of United States as per chart No. 1. (2) State conditions

of (*a*) barometer, (*b*) thermometer, (*c*) sky, and (*d*) wind directions before coming of low pressure storm from west. (3) State direction of forward movement.

2. Give direction and weather conditions in (*a*) eastern, (*b*) western, and (*c*) central part of United States as per chart No. 2. (2) State conditions of (*a*) barometer, (*b*) thermometer, (*c*) sky, and (*d*) wind directions before coming of anticyclone or high-pressure storm from the west.

3. Determine barometric gradient in (*a*) front and (*b*) rear of "low" in chart No. 1. (2) State which gradient is usually steeper, "front" or "rear." (3) Mention relation between gradient and wind velocity. (4) Read Salisbury, page 396. (5) How does distance between isobars indicate velocity of wind? (6) Read Waldo, page 100, Realm of Nature, 116.

4. State in what ways (*a*) wind directions, (*b*) wind velocity, (*c*) barometric gradients are shown upon weather maps. (2) State how (*a*) temperature, (*b*) pressure, (*c*) condition of sky are indicated upon weather map. (3) Examine charts.

5. Describe proper "storm signal" to be used in each quarter of storm. (2) What kind of signal is used in case of hurricane? (3) How are very strong winds indicated upon weather map? (4) Upon barographic sheet? (5) Name proper storm signals to be used in case of low-pressure storm coming from west.

III. Reference Books.

1. Tarr's Physical Geography, Chapter XIII.
2. Dryer's Physical Geography, Chapter XXVII.
3. Realm of Nature, Chapter IX.
4. Salisbury's Physiography, Chapter XVII.
5. Story of Atmosphere, Chapters I, X, XII.
6. Waldo's Elementary Meteorology, Chapters VIII, IX.
7. Davis's Elementary Meteorology, Chapter X.
8. Moore's Descriptive Meteorology, Chapter XIII.

EXERCISE XVII. SPECIAL WINDS AND STORMS.

I. Directions, etc.

1. Prepare explanation for (*a*) land breezes and (*b*) sea breezes. (2) Note (*a*) causes, (*b*) time of occurrences, and (*c*) direction of winds. (3) Read Realm of Nature, pages 122 to 126, and enlarge upon upper and lower halves of page, figures 25 and 26. (4) Read Davis, pages 134, 313; Waldo, page 262, or Moore, page 182, and prepare summary.

2. Draw upon upper and lower halves of page two maps of India, one for summer and one for winter. (2) Indicate upon maps (*a*) latitude, (*b*) mountains, (*c*) rivers. (*d*) wind directions, (*e*) rainfall in colors, (*f*) pressure lines, and (*g*) words "High" and "Low" in proper places. (3) Read Tarr, pages 257 and 284; Davis, page 123, or Moore, page 180. (4) Note (*a*) wind direction and (*b*) rainfall during (*a*) summer, (*b*) winter.

3. Determine what is meant by mountain and valley winds. (2) Prepare explanation for (*a*) causes and (*b*) time and place of occurrence, and (*c*) character of (*a*) Foehn, (*b*) Chinook, (*c*) Sirocco, and (*d*) Mistral. (3) Read Davis, page 137; Waldo, page 262. or Moore, page 184.

4. Read Waldo. page 287, or Moore, page 223, and prepare summary of what is said concerning cold and hot waves. (2) Read Moore, pages 185 to 188, and inspect charts Nos. 24, 25.

5. Insert upon upper and lower parts of page vertical and cross sections of hurricane, figures 426 and 428, Tarr. (2) Draw through center of figure two straight lines at right angles. (3) Note direction of spiral whirl in upper, center, and lower parts of figure 425. (4) Note direction of forward movement of storm. (5) What is meant by front and rear of storm? (6) Notice how storm is represented upon weather map in figure 427, also by barographic line, figure 297, Dryer.

II. Written Review.

1. State comparative temperature over land and water during day and night, summer and winter. (2) What effect has heat upon atmospheric pressure? (3) What causes land and sea breezes? (4) Mention some places where land and sea breezes are strong. (5) State about what time of day each wind occurs.

2. In what wind belt is India? (2) Why is India not desert like Arabia? (3) Explain what causes wind to blow toward and away from India periodically. (4) Account for periodical floods and droughts in India. (5) Describe in separate paragraphs (*a*) summer and (*b*) winter monsoon in India.

3. What causes mountain and valley wind? (2) Mention some effects of such winds upon temperature and life. (3) Describe Foehn or Chinook winds as to cause, time of occurrence, and character. (4) Read Davis, page 234, or Moore, page 186.

4. Give cause and character of some hot winds. (2) Do same in relation to cold winds. (3) State effect of such winds upon life. (4) Read Davis, pages 230–233.

5. Mention important features of hurricanes. (2) Explain why such storms are so destructive to buildings. (3) What places are considered safest during tornadoes? (4) When and where do hurricanes or typhoons occur frequently? (5) Describe ordinary (*a*) whirlwind, (*b*) hurricane, (*c*) typhoon, or (*d*) tornado. (6) Read Dryer, pages 318 to 323. (7) State how violent storms are indicated by (*a*) barograph, (*b*) thermograph, (*c*) wind directions, and (*d*) conditions of sky. (8) How are such storms indicated upon weather map? By storm signals?

III. Reference Books.

1. Tarr's Physical Geography, Chapter XIII.
2. Dryer's Physical Geography, Chapter XXVII.
3. Realm of Nature, Chapter IX.
4. Salisbury's Physiography, Chapter XVI.
5. Davis's Elementary Meteorology, Chapter VII.
6. Waldo's Elementary Meteorology, Chapter X.
7. Story of Atmosphere, Chapter IX.
8. Moore's Descriptive Meteorology, Chapters X–XIII.

EXERCISE XVIII. ATMOSPHERIC MOISTURE.

I. Directions, etc.

1. Record upon properly ruled paper condition of sky daily by using symbols upon United States weather maps. (2) Record kinds of clouds by using abbreviations shown upon United States cloud charts. (3) Examine charts and maps. (4) Read what is said in references regarding atmospheric moisture. (5) Insert upon properly ruled paper table, page 280, Dryer. (6) Note relation between saturated air and temperature.

2. Note what is said regarding (*a*) relative and (*b*) absolute humidity. (2) Note also effect of increase or decrease of temperature upon relative humidity. (3) Observe relative weight of dry air and water vapor. (4) Note change in volume from water to water vapor. (5) Read Realm of Nature, pages 42, 102, 104.

3. Draw from observation of instrument or pages 401–402, Dryer, hygrometer. (2) Determine by use of hygrometer and table, page 408, Dryer, relative humidity of room daily. (3) Explain drawing by means of letters. (4) Observe readings of each thermometer. (5) Determine which is lower. (6) Prepare explanation for difference. (7) See Exercise VII for scale for thermometers.

4. Make drawing of experiment to illustrate (*a*) evaporation and (*b*) condensation of moisture. (2) Letter different parts of drawing for explanation. (3) Note effect (*a*) of heat upon evaporation and (*b*) of cold upon condensation. (4) Insert table, page 147, Davis, and prepare explanation.

5. Observe from experiment what it is that causes condensation. (2) Enumerate four processes of cooling as given in Dryer, page 282. (3) State clearly substance of each paragraph separately. (4) Read carefully Chapter XII, Moore's Descriptive Meteorology.

II. Written Review.

1. Explain table in No. 1. (2) How much does water expand before it becomes water vapor? (3) What is cause of expansion? (4) Explain what is meant by saturated air. (5) Name five conditions favorable for evaporation. (6) Name five benefits arising from evaporation of moisture.

2. Define and give examples of (*a*) absolute humidity, (*b*) relative humidity, and (*c*) point of saturation. (2) State effects of (*a*) increase or (*b*) decrease of temperature upon humidity. (3) Give examples to illustrate meaning. (4) What is meant by "damp air"?

3. Describe in full hygrometer. (2) State how (*a*) relative humidity and (*b*) dew points are determined by hygrometer and table. (3) Explain why reading upon one thermometer is less than reading upon other thermometer. (4) State effect of evaporation upon temperature. (5) Explain why it is cooler after rains in summer. (6) Why are summers in western Washington cooler than summers in eastern Washington?

4. Explain experiment in No. 4. (2) Mention some favorable condition for condensation. (3) Substitute blades of grass for cold-jar experiment, and explain formation of dew. (4) Substitute cold dust particles for cold jar, and explain formation of fog and clouds. (5) Read Moore, pages 204, 205.

5. Mention four ways through which condensation is produced. (2) Explain formation of fogs off shore. (3) Explain formation of clouds about mountain tops. (4) Why do clouds accumulate with south winds and disperse with north winds?

III. Reference Books.

1. Dryer's Physical Geography, Chapter XXIII.
2. Sigsbee's Cloud Forms.
3. Moore's Descriptive Meteorology, Chapters VI, VII.
4. Tarr's Physical Geography, Chapter XII.
5. Waldo's Elementary Meteorology, Chapter V.
6. Harrington's "Weather," Chapters X, XI.
7. Salisbury's Physiography, Chapter XIV.
8. Davis's Elementary Meteorology, Chapter VIII.

EXERCISE XIX. MOISTURE (Continued).

I. Directions, etc.

1. Classify cloud forms. (2) See Government charts and read references to clouds. (3) Note form, height, etc., of each class. (4) Insert mean height in table, page 179, Davis, or page 111, Story of Atmosphere. (5) Note from table whether clouds are higher in summer or winter. (6) State reason for observation.

2. Prepare in separate paragraphs short explanations with examples to illustrate following ways of causing rain: (*a*) Thunder storms, (*b*) cyclones, (*c*) doldrums, (*d*) volcanoes, (*e*) mountains, (*f*) intermingling winds, (*g*) land and sea breezes, (*h*) southerly winds. (2) Read references to each topic, also rainfall.

3. Read Dryer, Chapter XXVIII. (2) Observe and prepare to explain cause and distribution of rainfall as represented upon summer and winter charts. (3) Insert four general laws governing distribution of rainfall as given on page 333, Dryer.

4. Reproduce from books or charts four snow crystals 2 inches in diameter. (2) Note number of sides to crystals. (3) Mention condition most favorable to formation of snow. (4) Read Waldo, page 159, or Realm of Nature, page 113.

5. Record daily (*a*) kinds of clouds observed, (*b*) weather conditions, and (*c*) wind directions. (2) Note daily relation between (*a*) kind of clouds, (*b*) kind of weather and direction of winds. (3) Notice conditions of barometer daily.

II. Written Review.

1. Enumerate in separate paragraphs chief features of each primary class of clouds. (2) Mention kind of weather usually associated with each class. (3) Read Realm of Nature, page 111, or Waldo, page 129.

2. Note general direction of mountain systems and prevailing winds upon each continent. (2) Compare height of rain-bearing clouds with height of mountains. (3) Locate rain and rainless belts. (4) State causes in each case. (5) What causes rain to fall upon oceans and plains?

3. Explain why clouds and rain should occur in front and center of low-pressure storms while sky is clear and cold in rear. (2) See Davis, page 228, and refer to diagrams of storms. (3) What effect has condensation of water vapor upon temperature? (4) Explain effect of rainfall upon temperature of western Washington.

4. Mention weather conditions favorable to formation of frost, ice, or snow. (2) Name some advantages of snow or ice as compared with rain. (3) Mention and give examples of advantages of snowfall to (*a*) water supply, (*b*) irrigation, (*c*) temperature, and (*d*) agriculture.

5. Mention kind of clouds that usually accompany low barometer and southwest winds. (2) What kind of weather do such clouds indicate? (3) Windy weather is indicated by what kind of cloud forms? (4) Cold weather with high barometer is usually accompanied by what kind of clouds? (5) Mention some uses of clouds.

III. Reference Books.

1. Dryer's Physical Geography, Chapter XXIII.
2. Tarr's Physical Geography, Chapter XII.
3. Story of Atmosphere, Chapters VII, VIII.
4. Moore's Descriptive Meteorology, Chapters XI, XII.
5. Waldo's Elementary Meteorology, Chapter V.
6. Davis's Elementary Meteorology, Chapter VIII.
7. Harrington's "Weather," Chapters X, XI, XII.
8. Salisbury's Physiography, Chapter XIV.

EXERCISE XX. THE OCEAN.

I. Directions, etc.

1. Draw in red upon chart of world thermal lines showing temperature of surface water. (2) Read Tarr, pages 182–184, and see figure 320, Tarr, or page 253, Dryer. (3) Insert and explain beneath, table, page 254, Dryer. (4) Note from chart and table where temperature is greatest and where least. (5) Prepare explanation.

2. Give short description of (*a*) wind waves and (*b*) storm waves. (2) Include in description (*a*) cause, (*b*) size, and (*c*) effect of waves upon shore line. (3) Determine what is meant by (*a*) crest, (*b*) trough, (*c*) length, and (*d*) height of waves. (4) Use delta table for demonstration. (5) Note relation between size of waves and angle of wind. (6) Velocity of wind and force of waves.

3. Draw four diagrams showing relative position of (*a*) earth, (*b*) moon, and (*c*) sun at (*a*) neap and (*b*) spring tides. (2) See Appendix E, Tarr, or Dryer, page 263. (3) Explain each diagram by letters. (4) Indicate sun's gravity by red lines. (5) Note difference in height of tide at (*a*) new, (*b*) full, and (*c*) quarter moon, and prepare explanation. (6) See diagrams, page 511, Salisbury.

4. Draw upon chart of world cotidal lines in each ocean. (2) See Realm of Nature, page 258. (3) Note directions of tidal waves in each ocean. (4) Observe effect of continents upon direction and height of tidal waves.

5. Place upon chart of world ocean currents, warm in red and cold in black, with names in proper places. (2) See Dryer, page 257, or Tarr, page 194. (3) Note directions of drift of (*a*) warm and (*b*) cold currents. (4) Which way would currents flow if earth stood still? (5) If earth rotated from east to west? (6) Compare temperatures near eastern and western coasts of continents. (7) See thermal charts, and read Moore, page 266.

II. Written Review.

1. State where sea water is (*a*) warmest and where (*b*) coldest. (2) Give reasons for each statement. (3) How do thermal lines upon ocean compare with thermal lines upon land? (4) Compare temperature of land with temperature of water in (*a*) summer and in (*b*) winter. (5) State how depth of water affects temperature. (6) See chart and table, and read Moore, pages 83–86.

2. Explain relation between (*a*) velocity of wind and force of waves, (*b*) angle of wind and size of waves. (2) Explain what is meant by (*a*) crest, (*b*) trough, (*c*) length, and (*d*) height of waves. (3) What is meant by (*a*) breakers and (*b*) undertow? (4) What effect have waves upon shore lines? Upon evaporation?

3. How are tides produced? (2) State what is meant by "tidal waves." (3) Give direction of tidal currents in north, south, and middle of each ocean. (4) Show how contents and shore lines affect (*a*) direction and (*b*) height of tidal water. (5) Explain how time of tides is determined. (6) Account for difference in time of tides in same and in different ports.

4. What causes ocean currents? (2) Of what importance are ocean currents to man? (3) Describe two currents, one warm and the other cold, in each ocean. (4) Give general effect of each current upon climate. (5) State effect of earth's rotation and continental masses upon direction of currents. (6) What effect have winds upon currents?

5. Record daily upon properly ruled paper conditions of tides in Tacoma for month, together with phases of moon. (2) See daily papers or tide tables, and observe tides daily in bay. (3) At what phase of moon is tide highest? (4) When is difference between high and low tides least? (5) How many feet difference between extreme high and low tides in Tacoma? (6) Show how tides assist in commerce.

III. Reference Books.

1. Tarr's Physical Geography, Chapter X.
2. Dryer's Physical Geography, Chapters XIX–XXI.
3. Salisbury's Physiography, Chapter XX.
4. Pilot Charts, Tide Tables.
5. Realm of Nature, Chapters X, XI.
6. Maury's Geography of Sea.
7. Shaler's Sea and Land.
8. Newcomb's Astronomy.